

WHAT IS CLAIMED IS:

1. A method of performing an efficient excitation quantization corresponding to a residual signal using a codebook in a speech or audio noise feedback coding (NFC) system, the NFC system including at least one noise feedback loop, the codebook including N vector quantization (VQ) codevectors, where N is an integer greater than one, the method comprising:

(a) deriving N correlation values using the NFC system, each of the N correlation values corresponding to a respective one of the N VQ codevectors;

(b) combining each of the N correlation values with a corresponding one of N ZERO-STATE energies of the NFC system, thereby producing N minimization values each corresponding to a respective one of the N VQ codevectors; and

(c) selecting a preferred one of the N VQ codevectors based on the N minimization values, whereby the preferred VQ codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal.

2. The method of claim 1, wherein step (a) comprises separately correlating a ZERO-INPUT response of the NFC system with each of N ZERO-STATE responses of the NFC system, each of the N ZERO-STATE responses corresponding to a respective one of the N VQ codevectors.

3. The method of claim 2, wherein the residual signal includes a series of residual vectors, the method further comprising performing steps (a), (b) and (c) for each of the residual vectors, thereby producing an excitation quantization corresponding to each of the residual vectors.

4. The method of claim 3, wherein the N ZERO-STATE responses are invariant over a series of successive residual vectors, the method further comprising:

for each of the residual vectors in the series of successive residual vectors, searching the codebook using the N invariant ZERO-STATE responses.

5. The method of claim 3, wherein the N ZERO-STATE energies are invariant over a series of successive residual vectors, the method further comprising:

for each of the residual vectors in the series of successive residual vectors, searching the codebook using the N invariant ZERO-STATE energies.

6. A method of searching a codebook in a speech or audio coding system, the codebook including a plurality of shape codevectors each associated with a positive codevector and a negative codevector, comprising:

(a) deriving a correlation term corresponding to one shape codevector by correlating

a ZERO-STATE response of the coding system corresponding to the shape codevector, with

a ZERO-INPUT response of the coding system;

(b) deriving a first minimization value corresponding to the positive codevector associated with the one shape codevector when a sign of the correlation term is a first value; and

(c) deriving a second minimization value corresponding to the negative codevector associated with the one shape codevector when the sign of the correlation term is a second value.

7. The method of claim 6, wherein the coding system is a noise feedback coding (NFC) system including at least one noise feedback loop, and

step (a) comprises deriving the correlation term corresponding to the one shape codevector based on both

a ZERO-STATE response of the NFC system corresponding to the one shape codevector, and

a ZERO-INPUT response of the NFC system.

8. The method of claim 6, further comprising:

(d) performing steps (a), (b) and (c) for each of the shape codevectors, thereby deriving for each shape codevector either a first minimization value corresponding to the positive codevector or a second minimization value corresponding to the negative codevector; and

(e) selecting a preferred codevector from among the positive and negative codevectors corresponding to minimization values derived in steps (a) and (b) based on the minimization values, whereby the preferred codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal.

9. The method of claim 8, wherein step (e) comprises selecting, as the preferred codevector, the positive or negative codevector corresponding to a minimum one of the minimization values.

10. The method of claim 8, wherein the residual signal includes a series of residual vectors, the method further comprising performing steps (a) through (e) for each of the residual vectors, thereby producing an excitation quantization corresponding to each of the residual vectors.

11. The method of claim 6, wherein:

step (b) comprises deriving the first minimization value corresponding to the positive codevector when the sign of the correlation term is negative; and

step (c) comprises deriving the second minimization value corresponding to the negative codevector when the sign of the correlation term is positive.

12. The method of claim 6, further comprising, prior to step (a):  
deriving the ZERO-INPUT response of the coding system; and  
deriving the ZERO-STATE response of the coding system.

13. The method of claim 6, further comprising, prior to step (b):  
deriving, from the ZERO-STATE response, a ZERO-STATE energy corresponding to the one shape codevector,  
wherein step (b) and step (c) each comprise combining the ZERO-STATE energy with the correlation term to produce the respective minimization value.

14. The method of claim 13, wherein:  
step (b) further comprises deriving the minimization value by adding the correlation term to the ZERO-STATE energy; and  
step (c) further comprises deriving the minimization value by subtracting the correlation term from the ZERO-STATE energy.

15. The method of claim 14, wherein:  
the positive codevector associated with each shape codevector is the shape codevector; and  
the negative codevector associated with each shape codevector is derived by negating the shape codevector.

16. The method of claim 8, wherein the codebook represents a product of  
a shape code,  $C_{shape} = \{c_1, c_2, c_3, \dots, c_{N/2}\}$ , including  $N/2$  shape codevectors  $c_n$ , and

a sign code,  $C_{\text{sign}} = \{+1, -1\}$ , including a pair of oppositely-signed sign values +1 and -1, such that the positive codevector and the negative codevector associated with each shape codevector  $c_n$  each represent a product of the shape codevector and a corresponding one of the sign values, and

wherein step (e) comprises selecting a shape codevector and a corresponding sign value corresponding to the preferred codevector, based on the minimization values.

17. A method of searching a codebook in a speech or audio noise feedback coding (NFC) system, the NFC system including at least one noise feedback loop, the codebook including a plurality of shape codevectors each associated with a positive codevector and a negative codevector, comprising:

for each shape codevector

(a) deriving a correlation term corresponding to the shape codevector using at least one filter structure of the NFC system;

(b) deriving a first minimization value corresponding to the positive codevector associated with the shape codevector when a sign of the correlation term is a first value; and

(c) deriving a second minimization value corresponding to the negative codevector associated with the shape codevector when a sign of the correlation term is a second value; and

(d) selecting a preferred codevector from among the positive and negative codevectors corresponding to minimization values derived in steps (b) and (c) based on the minimization values.

18. The method of claim 17, wherein step (a) comprises deriving the correlation term for the shape codevector based on both

a ZERO-STATE response of the NFC system corresponding to the shape codevector, and

a ZERO-INPUT response of the NFC system.

19. The method of claim 18, further comprising, prior to step (b): deriving, from the ZERO-STATE response, a ZERO-STATE energy corresponding to the shape codevector of step (a),

wherein step (b) and step (c) each comprise combining the ZERO-STATE energy with the correlation term to produce the respective minimization value.

20. The method of claim 18, wherein the preferred codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal, the residual signal including a series of residual vectors, the method further comprising:

performing steps (a) through (d) to produce a preferred codevector usable as an excitation quantization corresponding to each of the residual vectors.

21. The method of claim 18, wherein a plurality of ZERO-STATE responses corresponding to the plurality of shape codevectors are invariant over a series of successive residual vectors, the method further comprising:

searching the codebook using the plurality of invariant ZERO-STATE responses for each of the residual vectors in the series of successive residual vectors

22. The method of claim 18, wherein a plurality of ZERO-STATE energies corresponding to the plurality of shape codevectors are invariant over a series of successive residual vectors, the method further comprising:

searching the codebook using the plurality of invariant ZERO-STATE energies for each of the residual vectors in the series of successive residual vectors

23. A computer program product comprising a computer usable medium having computer readable program code means embodied in the medium for causing an application program to execute on a computer processor to perform an efficient excitation quantization corresponding to a residual signal using a codebook in a speech or audio noise feedback codec (NFC), the NFC including at least one noise feedback loop, the codebook including N vector quantization (VQ) codevectors, where N is an integer greater than one, the computer readable program code means comprising:

a first computer readable program code means for causing the processor to derive N correlation values using the NFC, each of the N correlation values corresponding to a respective one of the N VQ codevectors;

a second computer readable program code means for causing the processor to combine each of the N correlation values with a corresponding one of N ZERO-STATE energies of the NFC, thereby producing N minimization values each corresponding to a respective one of the N VQ codevectors; and

a third computer readable program code means for causing the processor to elect a preferred one of the N VQ codevectors based on the N minimization values, whereby the preferred VQ codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal.

24. The computer program product of claim 23, wherein the first program code means includes computer readable program code means for causing the processor to separately correlate a ZERO-INPUT response of the NFC with each of N ZERO-STATE responses of the NFC, each of the N ZERO-STATE responses corresponding to a respective one of the N VQ codevectors.

25. The computer program product of claim 24, wherein the residual signal includes a series of residual vectors, and

wherein the first, second and third program code means perform their respective functions for each of the residual vectors, thereby producing an excitation quantization corresponding to each of the residual vectors.

26. The computer program product of claim 25, wherein the N ZERO-STATE responses are invariant over a series of successive residual vectors, the computer program product further comprising:

a fourth computer readable program code means for causing the processor to search the codebook using the N invariant ZERO-STATE responses for each of the residual vectors in the series of successive residual vectors.

27. The computer program product of claim 25, wherein the N ZERO-STATE energies are invariant over a series of successive residual vectors, the computer program product further comprising:

a fourth computer readable program code means for causing the processor to search the codebook using the N invariant ZERO-STATE energies for each of the residual vectors in the series of successive residual vectors.

28. A computer program product comprising a computer usable medium having computer readable program code means embodied in the medium for causing an application program to execute on a computer processor to search a codebook in a speech or audio codec, the codebook including a plurality of shape codevectors each associated with a positive codevector and a negative codevector, the computer readable program code means comprising:

a first computer readable program code means for causing the processor to derive a correlation term corresponding to one shape codevector by correlating

a ZERO-STATE response of the codec corresponding to the shape codevector, with

a ZERO-INPUT response of the codec;

a second computer readable program code means for causing the processor to derive a first minimization value corresponding to the positive codevector associated with the one shape codevector when a sign of the correlation term is a first value; and

a third computer readable program code means for causing the processor to derive a second minimization value corresponding to the negative codevector associated with the one shape codevector when the sign of the correlation term is a second value.

29. The computer program product of claim 28, wherein the codec is a noise feedback codec (NFC) including at least one noise feedback loop, and wherein the first program code means includes computer readable program code means for causing the processor to derive the correlation term corresponding to the one shape codevector based on both

a ZERO-STATE response of the NFC corresponding to the one shape codevector, and

a ZERO-INPUT response of the NFC.

30. The computer program product of claim 28, wherein:

the first, second and third program code means perform their respective functions for each of the shape codevectors, thereby deriving for each shape codevector either a first minimization value corresponding to the positive codevector or a second minimization value corresponding to the negative codevector; and

.the computer readable program means further comprises

a fourth computer readable program code means for causing the processor to select a preferred codevector from among the positive and negative codevectors corresponding to minimization values derived by the second and third program code means based on the minimization values, whereby the preferred codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal.

31. The computer program product of claim 30, wherein the fourth program code means includes computer readable program code means for causing the processor to select, as the preferred codevector, the positive or negative codevector corresponding to a minimum one of the minimization values.

32. The computer program product of claim 30, wherein the residual signal includes a series of residual vectors, and wherein the first, second, third and fourth program code means perform their respective functions for each of the residual vectors, thereby producing an excitation quantization corresponding to each of the residual vectors.

33. The computer program product of claim 28, wherein:  
the second program code means includes computer readable code means for causing the processor to derive the first minimization value corresponding to the positive codevector when the sign of the correlation term is negative; and

the third program code means includes computer readable code means for causing the processor to derive the second minimization value corresponding to the negative codevector when the sign of the correlation term is positive.

34. The computer program product of claim 28, wherein the computer readable program code means further comprises:

a fifth computer readable program code means for causing the processor to derive the ZERO-INPUT response of the codec before the correlation term is derived; and

a sixth computer readable program code means for causing the processor to derive the ZERO-STATE response of the codec before the correlation term is derived.

35. The computer program product of claim 28, wherein the computer readable program code means further comprises

a fifth computer readable program code means for causing the processor to derive, from the ZERO-STATE response and before the first minimization value is derived, a ZERO-STATE energy corresponding to the one shape codevector,

wherein

the second program code means includes computer readable program code means for causing the computer to combine the ZERO-STATE energy with the correlation term to produce the first minimization value, and

the third program code means includes computer readable program code means for causing the computer to combine the ZERO-STATE energy with the correlation term to produce the second minimization value.

36. The computer program product of claim 35, wherein:

the second program code means further includes computer readable program code means for causing the computer to derive the first minimization value by adding the correlation term to the ZERO-STATE energy; and

the third program code means further includes computer readable program code means for causing the computer to derive the second

minimization value by subtracting the correlation term from the ZERO-STATE energy.

37. The computer program product of claim 36, wherein:

- the positive codevector associated with each shape codevector is the shape codevector; and
- the negative codevector associated with each shape codevector is derived by negating the shape codevector.

38. The computer program product of claim 30, wherein the codebook represents a product of

- a shape code,  $C_{shape} = \{c_1, c_2, c_3, \dots, c_{N/2}\}$ , including  $N/2$  shape codevectors  $c_n$ , and
- a sign code,  $C_{sign} = \{+1, -1\}$ , including a pair of oppositely-signed sign values  $+1$  and  $-1$ , such that the positive codevector and the negative codevector associated with each shape codevector  $c_n$  each represent a product of the shape codevector and a corresponding one of the sign values, and

wherein the fourth program code means includes computer readable program code means for causing the processor to select a shape codevector and a corresponding sign value corresponding to the preferred codevector, based on the minimization values.

39. A computer program product comprising a computer usable medium having computer readable program code means embodied in the medium for causing an application program to execute on a computer processor to search a codebook in a speech or audio noise feedback codec (NFC), the NFC including at least one noise feedback loop, the codebook including a plurality of shape codevectors each associated with a positive codevector and a negative codevector, the computer readable program code means comprising:

a first computer readable program code means for causing the processor to derive, for each shape codevector, a correlation term corresponding to the given shape codevector using at least one filter structure of the NFC;

a second computer readable program code means for causing the processor to derive, for each shape codevector, a first minimization value corresponding to the positive codevector associated with the given shape codevector when a sign of the correlation term is a first value; and

a third computer readable program code means for causing the processor to derive, for each shape codevector, a second minimization value corresponding to the negative codevector associated with the given shape codevector when a sign of the correlation term is a second value; and

a fourth computer readable program code means for causing the processor to select a preferred codevector from among the positive and negative codevectors corresponding to minimization values derived by the first and second program code means based on the minimization values.

40. The computer program product of claim 39, wherein the second program code means includes computer readable program code means for causing the processor to derive the correlation term for the given shape codevector based on both

a ZERO-STATE response of the NFC corresponding to the given shape codevector, and

a ZERO-INPUT response of the NFC.

41. The computer program product of claim 40, wherein the computer readable program code means further comprises:

a fifth computer readable program code means for causing the processor to derive, from the ZERO-STATE response and before the second program code means derives a first minimization value, a ZERO-STATE energy corresponding to the given shape codevector,

wherein

the second program code means includes computer readable program code means for causing the processor to combine the ZERO-STATE energy with the correlation term to produce the first minimization value, and

the third program code means includes computer readable program code means for causing the processor to combine the ZERO-STATE energy with the correlation term to produce the second minimization value

42. The computer program product of claim 40, wherein the preferred codevector is usable as an excitation quantization corresponding to a residual signal derived from a speech or audio signal, the residual signal including a series of residual vectors, and

the first, second, third and fourth program code means perform their respective functions to produce a preferred codevector usable as an excitation quantization corresponding to each of the residual vectors.

43. The computer program product of claim 40, wherein a plurality of ZERO-STATE responses corresponding to the plurality of shape codevectors are invariant over a series of successive residual vectors, and

the computer readable program code means further comprises a sixth computer readable program code means for causing the processor to search the codebook using the plurality of invariant ZERO-STATE responses for each of the residual vectors in the series of successive residual vectors.

44. The computer program product of claim 40, wherein  
a plurality of ZERO-STATE energies corresponding to the plurality of  
shape codevectors are invariant over a series of successive residual vectors,  
and

the computer readable program code means further comprises a sixth computer readable program code means for causing the processor to search the codebook using the plurality of invariant ZERO-STATE energies for each of the residual vectors in the series of successive residual vectors.

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